conjectured that the molecule of hydrogen chloride is not broken down in its union with ammonia to form ammonium chloride. Should this conjecture not be accepted as correct, it will be necessary to seek for an explanation of the phenomena observed by some relations yet to be discovered.

V. "On the Phenomena accompanying Stimulation of the Gland-Cells in the Tentacles of *Drosera dichotoma*." By WALTER GARDINER, M.A., Fellow of Clare College, Cambridge, Demonstrator of Botany in the University. Communicated by Professor M. FOSTER, Sec. R.S. Received September 5, 1885.

(Preliminary Communication.)

Method of Research.—Pieces of unstimulated leaves, and of leaves stimulated for periods varying from 5 minutes to 72 hours, were examined fresh, or after treatment with alcohol, picric acid, chromic acid, or osmic acid. The most satisfactory results were obtained from specimens treated for 12 hours with 1 and 2 per cent. chromic acid; such strengths dissolving the tannin precipitate first formed, and fixing the structures most successfully. The leaves were fed principally upon small flies or pieces of frog muscle, since these were found to succeed best. Heat stimuli, electrical stimuli, and stimulus produced by contact or cutting were also employed.

General Histology.—As regards the general histology of the tentacles, one may notice that the gland-cells of the head are provided with delicate uncuticularised cell-walls, which are remarkably pitted on their upper or free surfaces; that the rest of the epidermal cells of the tentacles have their exterior walls excessively cuticularised and resistant, and that their radial longitudinal walls are freely pitted.

Structure of the Resting Gland-Cells.—In the typical resting gland-cell, the protoplasm is arranged in a network or reticulum. The meshes of this reticulum are excessively close around the nucleus, which is situated at the base of the cell, but towards the free surface they are much more open; the close and more open arrangement merging the one into the other. The meshwork extends through the whole of the cell cavity, and the interstices between the meshes are occupied by the pink cell sap; the whole being bounded by the ectoplasm. The gland-cells at the base of the head differ somewhat in structure from the more apical cells, as also do all the cells of the short stalked tentacles which are situated at the centre of the leaf. In neither of the three layers of cells covering the tracheïdal cells of the head could any obvious movement of the protoplasm be detected.

The epidermal cells of the stalk of the tentacles possess in the resting condition the following structure. In each cell there is a lenticular nucleus, and chlorophyll grains are present on the side of the wall next the vascular bundle. These structures are situated in the ectoplasm, and take no part in the movement of rotation. In addition to these a body, which is usually spindle-shaped or acicular, is present in the cell, and generally occupies such a position that it stretches diagonally across the cell from end to end, the two extremities being embedded in the cell protoplasm. I shall speak of this body at present as the *plastoid*, on account of certain resemblances it bears as regards its microchemical reactions to plastids. This name may possibly, however, not be retained. The plastoid is fixed to some extent by absolute alcohol or chromic acid. With dilute alcohol it swells up and disappears. With iodine it becomes disorganised and spherical. It is best fixed by watery picric acid, and stains very readily and at once with Hofmann's blue. In the resting stage the plastoid takes no part in the movements of the rotating endoplasm. It is present in all the epidermal cells of the leaf except the gland-cells and the cells immediately beneath the same, and in the bending portion of those tentacles which execute movements, it is very large in the cells of the convex, and very small or even apparently absent in those of the concave side. In Dionæa it also occurs, being large in the cells of the upper surface of the leaf, and very small in those of the under. The cells themselves of the under surface in Dionæa and of the concave side in Drosera are also smaller than the others of the opposite side. The protoplasm of the tentacle cells is very clear and hyaline, and the whole protoplasmic utricle is thin and closely pressed against the cell-wall.

Changes in the Gland-Cells during Secretion.—The cells may be made to secrete by the combined stimulus of heat and moisture, by direct contact, or by electrical stimulus, but especially by the stimulus of food applied to the gland.

The histological changes which occur are the following. After some time (24 hours) a gland mounted in water exhibits a mottled appearance, such mottling being caused by a vacuolation of the most peripheral portions of the protoplasm of the gland-cells. In section such a cell shows, that in the course of secretion there has been a using up of the cell contents, and instead of the meshwork occupying the whole of the peripheral portion of the cell, so as to give a fairly homogeneous appearance, large spherical cavities have appeared in the reticulum here and there: such cavities being occupied by the cell sap. The sap has, moreover, assumed a much darker pink tint. Thus a breaking down or destruction of some part of the reticulum has taken place. After some 72 hours' stimulation this breaking down of the reticulum has reached to such an extent that in the peripheral portion

before referred to, all the central core of the meshwork has for the most part disappeared, and replacing it is a single large vacuole filled with cell sap. The ectoplasm has moreover contracted from the upper or free surface of the cell-wall. In no case does this destruction and consequent vacuolation extend to the base of the gland-cells where the nucleus is situated. The nucleus is always surrounded by dense protoplasm; and there are grounds for believing that after very long stimulation, when all the secretion has been poured out, and before absorption begins, an active growth of protoplasm takes place around the nucleus and in the more basal portion of the cell. In certain cases the secretion can be seen under the microscope to escape in drops—apparently through the pitted portions of the cell-wall—and the drops rapidly taking up water and being forced outwards, assume a rod-like form, and present a halo-like appearance around the gland. This also occurs in the mucilage-secreting cells of the bladders of Utricularia. The exact part taken by the layer of cells beneath the gland-cells has yet to be determined. After stimulation their vacuoles are occupied by large drops of cell sap, which is of a purple or even black colour.

The view here taken (which is supported by certain of the staining reactions) with regard to secretion is, that in the gland-cells the mere peripheral network consists of protoplasm, together with some formed substance derived from it, and that the outpouring of the secretion is caused by the repeated breaking down (owing to stimulation) of the protoplasm into this formed substance, which is of a mucous nature, and which rapidly attracts water and so escapes, as the secretion to the external surface.

Changes in the Stalk Cells.—The chief phenomena induced in the stalk cells either by contact by electrical stimulus or by feeding are, that the protoplasmic utricle swells up and encroaches on its own vacuole, that granules rapidly appear in the protoplasm, and that the movements of rotation increase in vigour. Also the cell becomes less turgid, and after long stimulation the plastoid and the nucleus both tend to become spherical. These changes are most markedly exhibited in tentacles stimulated with food. The protoplasm in swelling up abstracts water from its own vacuole, and in so doing leaves the tannin in the sap, in a comparatively concentrated condition. The outlines of the protoplasmic utricle are now rendered clearer than before. As previously stated, the movements of rotation become quickened very considerably, and numerous waves with high crests appear on the surface of the protoplasmic utricle, and are well registered by the corresponding disturbances in the cell sap. The phenomenon of the protoplasmic waves breaking over the nucleus with crests reaching nearly across the vacuole is very remarkable. The long and narrow shape of the cells, and the combined swelling of the

protoplasm, increase of rate of rotation and wave movements, cause the cell sap to be so disturbed, and as it were churned up, that drops of the sap become cut off from the main mass, and at last the whole of the sap is separated into numerous distinct portions which are suspended in the protoplasm as oily drops, and are carried round in the currents, presenting the appearance of moving droplets, pear-shaped bodies, and long string-like processes. The cell in this condition was known to Darwin as "aggregated." When movement ceases, as often naturally occurs, owing to excessive secretion, or can be induced by suddenly crushing the tentacle head, the variously shaped masses become spherical, and lie quiescent in the protoplasm. The aggregation produced by the action of ammonic carbonate is somewhat different from that brought about by feeding, and may be spoken of as passive as opposed to active aggregation. In this case the protoplasm abstracts water from the vacuole in the usual way, and, steadily swelling, chops up the tannin-loaded sap of the long and narrow cells into separate globules. The rotatory movements cause these globules to alter their form, but the movements in question are nothing like so vigorous as in the food-stimulated gland, and the globules are rarely, if ever, carried bodily about.

When the protoplasm swells and the cell becomes aggregated, the latter always loses its turgidity, and the state of aggregation is accompanied by a loss of water. Injection of water into the tissue will at once stop aggregation and restore the cell to its normal condition. Sometimes after active secretion (48 hours), the movements of the protoplasm of the topmost tentacle stalk cells will stop, and much of the protoplasm of each cell now collects to the end of the cell nearest the gland. Mounting in water will then restore the movements. It was found experimentally that the collecting of the protoplasm to one end was occasioned by the upward passage of water to the gland. If a passage of water be set up in an opposite direction, then the protoplasm collects to the opposite end.

When the more rapid movements of the protoplasm commence owing to stimulation, the plastoid usually becomes bent, and then either contracts and assumes a lenticular form, or becomes separated into two or more pieces each of which becomes lenticular. Later on further contraction ensues, and the plastoid is carried round the cell in the protoplasmic stream. The more the cells lose their turgidity, the more does the plastoid tend to assume a spherical form. Its spindle-shaped elongated form may, however, be restored by again bringing about turgidity, *e.g.*, by injection of water into the tissue. Thus the plastoid may be regarded as a turgometer, since it indicates the state of turgidity of the cell. On account of certain experiments and observations the author is led to believe that all differences of turgidity in cells are brought about by the protoplasm swelling and

becoming porous, and that the method of establishing a loss of turgidity by solutions of neutral salts and the like involves a state of things essentially different from that which normally occurs. In the one case the protoplasm itself undergoes change. In the other the cell sap is violently abstracted by artificial means from the vacuole of a protoplasmic utricle which is endeavouring to protect itself from the action of the reagent.

Movements of the tentacles may be brought about by direct contact and by cutting or injury, by electric stimulus, by the addition or withdrawal of water, and especially by the stimulus of food. In all these cases the stimulant upsets the existing equilibrium and brings about a difference of turgidity on the two opposite sides. Loss of water by plasmolysis usually induces movement, unless the salts employed have a specific action upon the protoplasm. Movement may occur without aggregation, and secretion may occur without movement, but whenever well-defined aggregation takes place, movement always follows. Different strengths of the same reagent may bring about different reactions. Thus a 0·1 per cent. solution of chromic acid causes both movement and secretion, while with a 1 or 2 per cent. solution neither phenomenon occurs. Among the curious effects of various salt solutions that of ammonic chloride may be noted, in that it acts markedly as a sedative, toning down aggregation and restoring turgidity. It was very generally noticed that the tentacles before becoming inflected, moved downwards and backwards, and that the upward and inflected movement subsequently took place. When a tentacle has become well inflected it can be observed that at the bending point the cells of the convex side are very turgid, with their plastoids spindle shaped, and that little or no aggregation has taken place, while in the cells of the concave side, on the other hand, there is well-marked aggregation and loss of turgidity ; the aggregation after a time extends to the convex side, the cells of which, in their turn, lose their turgidity, and at this stage all the cells are flaccid. Later on the cells of the concave side first regain their turgidity, and now the tentacle is bent back to its original position before stimulation. From certain observations on Dionæa and Mimosa, the author is led to believe that there also movement is made possible by the establishing of sudden and different conditions of turgidity of different cells, such differences being occasioned by the induced porosity of the protoplasm of certain of these cells. These phenomena occur perhaps in all cases of movement.

The plastoid markedly decreases in size after long stimulation in both Dionæa and Drosera. There are therefore some grounds for believing that it consists mainly of some reserve material or some substance which is used up during secretion. Whether the crystalloids in the nucleus of Pinguicula serve a similar purpose remains to

be seen, for at any rate a plastoid is not present. A somewhat casual examination was also made of many organs of movement, but in them no plastoid was observed. In *Drosera rotundifolia* and other species plastoids occur which resemble those of *Drosera dichotoma.* Strong single induction shocks or tetanising currents cause the plastoid to assume the spherical condition, or very frequently to break up into a string of small spheres. A sudden blow on the cover slip also causes the assumption of the spherical form. Moderately strong tetanising shocks cause swelling of the protoplasm, and increase of rapidity of movement and granularity. Very strong shocks may cause the contraction of the primordial utricle from the cell-wall at certain small areas, but immediate death always ensues, since the stimulus required is abnormally great. The normal effect of a regulated stimulus is to induce a swelling of the protoplasm and a loss of turgidity, and in consequence of the unequal reaction of the various cells to such a stimulus, movement of the tentacle also occurs.

[Note.—I have decided to name the body which I have provisionally spoken of as the plastoid "the rabdoid" (Gk. *rabdos*, a stick or wand). The change in form of the rabdoid appears to be a consequence of the molecular changes in the protoplasm. Differences of turgidity are among the results of these changes.—Nov. 28, 1885.]

VI. "On Variations in the Amount and Distribution of Fat in the Liver-Cells of the Frog." By J. N. Langley, M.A., F.R.S., Lecturer on Histology in the University of Cambridge. Received September 23, 1885.

I have in a previous paper* mentioned some of the changes which occur in certain circumstances in the number and arrangement of the fat-globules in the liver-cells of the frog. From observations made since that time at different seasons of the year, I have been able to ascertain certain points undetermined in the previous account.

Variations in the Amount and Distribution of Fat with the time of Year.—The fat in the liver-cells is at its maximum amount in February and March. In January it is, as a rule, somewhat less. In April it rapidly decreases; from May until December it is present in comparatively small though varying amount. It is usually present in minimum amount in September and October.

Generally speaking, the fat-globules form an inner zone in frogs which have hungered more than a week. In January, February, and March, however, the fat-globules are commonly more numerous in the outer part of the cells, often forming a distinct outer zone.

* "Proc. Roy. Soc.," vol. 34, p. 20.